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DEMAND FOR AQUACULTURE PRODUCTS IN TAIWAN: AN APPLICATION OF THE GENERALIZED MODEL

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□ *Policy decisions on what aquaculture products to develop require information on consumer demand for cultured species. However, information on the structure of demand for aquaculture products is limited and what few studies there are in Taiwan, where aquaculture is a major industry, suffer from methodological problems. To clear up some of these problems, we used modified nonnested testing techniques and performance forecasting to determine which generalized models could best estimate the demand for Taiwanese aquaculture products. The results of modified non-nested testing of the aquaculture demand system showed that prices predetermined and quantities predetermined could be used to estimate demand. The generalized ordinary demand model was able to better forecast performance than the generalized inverse demand model. We used the likelihood ratio test to discriminate among the four competing models for the generalized ordinary model; the AIDS model could be more suitably applied to the data. A more general model that is able to incorporate different dynamic structures (partial adjustment, first autoregressive, and static). This general framework is applied to the AIDS model. The first autoregressive AIDS model we used to calculate the own and cross-price elasticities for milkfish, tilapia, shrimp, shellfish, and carps found that price elasticities varied across fish type, that some products had high long-run own price elasticities, and that the demand for aquaculture products was largely determined by inertia.*

Keywords ordinary and inverse demand systems, aquaculture products, price elasticity

INTRODUCTION

Taiwan, a large island of close to 22,000,000 people, has a 300-year aquaculture history. Its output and value production play an important role in the economy of Taiwan, which, in 2000, had 62,567 hectares devoted to

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aquaculture alone. In 2000, production was valued at NT$26 billion, 29% of the production of the entire fishery.

Aquaculture is very important. It provides man with a source of animal protein as well as a source of income. Policy decisions on what aquaculture products to develop require information on consumer demand for cultured species and how that demand is likely to change as income and relative price change. However, the few studies on the structure of aquaculture product demand in Taiwan have methodological problems.

Given the importance of aquaculture products to the diet of the Taiwanese, others have previously attempted to model consumer demand for aquaculture products in Taiwan. In one study using monthly transaction data from fish markets in five inverse demand models, Chiang and Lee (2000) estimated consumer demand for milkfish, tilapia, and other aquaculture fishes in Taiwan. The assumption of their study, as well as others, is that demand is price driven, while other factors may be more important. In fact, consumer preferences for aquaculture products reflect relative lack of knowledge about which ordinary and inverse demand models could best estimate demand for Taiwanese aquaculture products. The issue of the best functional form is addressed within generalized specifications of inverse and ordinary demands (Barten 1993; Brown et al. 1995). The advantage of the generalized specifications is that they nest either a number of ordinary or inverse demand systems, which would make it possible to parameterize both ordinary and inverse systems in a way that comparisons among systems can be made (Eales et al. 1997).

Thus, this study aims to explore relevant model specifications, including the choice of an appropriate demand model and functional form, while attempting to estimate the demand for selected aquaculture products and the effect of changes in consumers' preferences towards aquaculture products and their substitutes.

The Evolution of Five Aquaculture Products Consumption in Taiwan

Table 1 shows the percent share of Taiwan's annual expenditures on five aquaculture products and the average retail price for each product for the years 1979 and 1998 as well as the sample mean for each product over the 20-year period. In 1998, the highest was 58.2% spent on shrimp; the lowest was 0.3% spent on tilapia. In between were milkfish, shellfish, and carp (18.2%, 22.2%, and 1.2%) the same year.

Expenditures on tilapia decreased from 9.6% in 1979 to 0.3% in 1998, with a 20-year average of 10.4%. Expenditures on milkfish and carp (15.3% and 1.8%) remained relatively constant over the same 20-year period. Expenditures on shellfish decreased from 25.1% in 1979 to 22.2% in

TABLE 1 The Expenditure Shares and Market Prices of Five Aquaculture Products in Taiwan from 1979 to 1998

Year	Tilapia	Milkfish	Carp	Shrimp	Shellfish
Expenditure share (%)					
1978	9.6	18.7	1.32	45.3	25.1
1998	0.3	18.2	1.31	58.2	22.2
Mean	10.4	15.3	1.82	49.6	23.0
Retailer price (NT$/Kg)					
1978	66.1	118.7	43.8	158.8	227.5
1998	64.1	83.4	82.4	344.6	124.0
Mean	66.1	119.2	65.1	219.1	155.1

Source: *Fisheries Statistical Yearbook Taiwan Area*, and *Taiwan Agricultural Prices and Costs Monthly*.

1998, with a 20-year average of 23.0%. Shrimp consumption grew the fastest, with expenditures growing from 45.3% in 1979 to 58.2% in 1998. The 20-year average was 49.6%.

The average prices of tilapia, milkfish, carp, shrimp, and shellfish are also reported in Table 1. Except for carp and fish, the retail price of aquaculture products decreased from 1978 to 1998. Carp almost doubled in retail price, and the price of shrimp increased more than twofold. The retail price of tilapia changed very little, but that of milkfish and shellfish decreased by 70% and 50%.

METHODOLOGY

In a study by Eales et al. (1997), the ordinary and inverse demand models could be re-parameterized to almost ideal demand system (AIDS) dependent variables. The generalized inverse demand model with AIDS dependent variables can be represented as:

$$d\omega_i = (e_i + d_1\omega_i)\mathrm{dln}Q + \sum_j (e_{ij} + d_2\omega_1(\delta_{ij} - \omega_j))\mathrm{dln}q_j \qquad (1)$$

where the e's are coefficients, d_1 and d_2 nesting parameters that yield the four inverse demand models, w_i expenditure share, q_i and dlnQ the quantity of the ith aquaculture product and Divisia volume index, and δ_{ij} the Kronecker delta. The parametric restrictions of the generalized inverse demand model can be represented as:

$$\begin{aligned} &\Sigma_i e_i = -d_1 \text{ and } \Sigma_i e_{ij} = 0 \quad \text{(adding up)} \\ &\Sigma_i e_{ij} = 0 \quad \text{(homogeneity)} \\ &e_{ij} = e_{ji} \quad \text{(symmetry)} \end{aligned} \qquad (2)$$

The generalized ordinary demand model with AIDS dependent variables can be represented as:

$$d\omega_i = (e_i' + \eta_1\omega_i)d\ln Q + \sum_j [e_{ij}' + \eta_2\omega_i(\delta_{ij} - \omega_j)]d\ln p_j \tag{3}$$

where the e's are coefficients, η_1 and η_2 nesting parameters that yield the four ordinary demand models, p_i the price of the ith aquaculture product, and the variables (w_i, q_i, δ_{ij}, and dlnQ) are as previously defined. The parametric restrictions of generalized ordinary demand model can be represented as:

$$\begin{aligned} \Sigma_i e_i' &= -\eta_1 \text{ and } \Sigma_i e_{ij}' = 0 \quad \text{(adding up)} \\ \Sigma_j e_{ij}' &= 0 \quad \text{(homogeneity)} \\ e_{ij}' &= e_{ji}' \quad \text{(symmetry)} \end{aligned} \tag{4}$$

The restrictions on the generalized models [(1) and (3)] that yield alternative functional forms are shown in Table 2. The likelihood ratio test (LRT) for model selection can represented as:

$$\text{LRT} = -2[\log \text{L}(\theta^*) - \log \text{L}(\theta)] \tag{5}$$

where the θ^* in the inverse demand model is the vector of parameter estimates of either the inverse Rotterdam model, the inverse AIDS model, the inverse Central Bureau of Statistics (CBS) demand model (Laitinen & Theil 1979; Keller & Driel 1985), or the inverse National Bureau of Research (NBR) demand model (Neves 1987). θ is the vector of parameter estimates of the generalized inverse model. θ^* in the ordinary demand model is the vector of parameter estimates of either the Rotterdam, the AIDS, the CBS, or the

TABLE 2 Restrictions on the Generalized Models that Yield Alternative Functional Forms

	Restrictions	
Model	d1	d2
Inverse Rotterdam	1	1
Inverse CBS	0	1
Inverse AIDS	0	0
Inverse NBR	1	0
	η	η
Rotterdam	–1	1
CBS	0	1
AIDS	0	0
NBR	–1	0

Note: Notation follows that of Equations (1) and (3) in the text.

TABLE 3 Flexibilities and Elasticities for the Generalized Demand Models

	Ordinary	Inverse
Compensated price elasticity/flexibility	$\varepsilon^*_{ij} = e'_{ij}/w_i - \eta_2\ (\delta_{ij} - w_j)$	$f^*_{ij} = e_{ij}/w_i + (d_2 - 1)(\delta_{ij} - w_j)$
Income elasticity scale flexibility	$\varepsilon_i = e'_i/wi + \eta_1 + 1$	$f_i = e_i/w_i + d_1 - 1$
Uncompensated price elasticity/flexibility	$\varepsilon_{ij} = (e'_{ij} - e'_i w_j)/w_i + (\eta_2 - 1)\ \delta_{ij} - (\eta_1 + \eta_2) w_j$	$f_{ij} = (e_{ij} + e_i w_j)/w_i + (d_2 - 1)\ \delta_{ij} + (d_1 - d_2) w_j$

Note: Notation follows that of Equations (1) and (3) in the text.

NBR, θ is the vector of parameter estimates of the generalized ordinary model, and logL() is the log value of the likelihood function. The formulae for flexibilities and elasticities for generalized models are given in Table 3.

We used modified nonnested testing techniques (Davidson & Mackinnon 1983) and forecasting performance to find out which of the generalized models would best estimate demand for Taiwanese aquaculture products. Davidson and Mickinnon's p-test requires modification to account for endogeneity of alternative model's right-hand-side variables. To overcome this, we specified first-order lags of logarithms of all potentially endogenous right-hand-side variables (e.g., quantities and scale in the inverse demands, and price and expenditure in the ordinary demands) as instrument for each demand model. Forecasting performance using root mean square errors (RMSE) was used to find out which of two general models would best estimate demand.

Data

We collected quarterly price and quantity data for the time period between 1979 and 1998 from *Fisheries Statistical Yearbook Taiwan Area, Taiwan Agricultural Prices and Costs Monthly*, and *Taiwan Statistical Data Book*. Per capita consumption was calculated based on population in the middle period of each year. Data on all prices were deflated by CPI (1996 = 100).

There are a myriad of aquaculture products. To make analysis more manageable, tilapia, milkfish, silver carp, grass carp, common carp, grass shrimp, kuruma shrimp, other shrimps, oysters, and hard clams were aggregated into five categories: tilapia, milkfish, shrimp (grass shrimp, kuruma shrimp, and other shrimps), shellfish (including oysters and hard clams), and carp (silver carp, grass carp, and common carp).

MODEL SELECTION

The results of the modified non-nested tests result of the general demand models are in Table 4. The first column of statistics in the table gives results of testing the generalized inverse model against the

TABLE 4 Modified Non-nested Tests of Generalized Demand Models

Null versus alternative models	Chi-squared statistic	Critical value (5%)
Inverse versus ordinary	3.071(4)[1]	9.48
Ordinary versus inverse	1.929(4)	9.48

[1]Figure in parentheses is degree of freedom.

generalized ordinary model, the inverse model is not rejected by ordinary at the 5% level of significance, and the chi-squared statistic is 3.071. The second column of statistics in the Table 4 gives results of testing the generalized ordinary model against the generalized inverse model, the ordinary model is not rejected by inverse as well, and the chi-squared statistic is 1.929. Therefore, the results of modified nonnested testing of the aquaculture demand system showed that prices and quantities predetermined could be used to estimate demand. The forecasting performance of the generalized inverse model did not perform as well as the generalized ordinary model using RMSE measures (Table 5).

We used the likelihood ratio test to discriminate among the four competing models for the generalized ordinary model. Adding-up, homogeneity, and symmetry conditions were imposed. Table 6 shows the log-likelihood value and corresponding test statistics for each of the models. In the first column are the log-likelihoods for the generalized ordinary model and four ordinary competing models. In the second column are likelihood-ratio test statistics for model selection; the third column has numbers representing freedom. The AIDS model is not rejected by the generalized ordinary model at the 5% level of significance, indicating that the AIDS model could be more suitably applied to the data than the other three models (Table 6).

Consumer demand for aquaculture products is not static, and lagged values of some of the variables influence current consumption (Brown 1952; Houthakker & Taylor 1970; Phlips 1983; Gracia et al. 1998). This dynamic behavior has been incorporated into generalized models using the same approach developed by Anderson and Blundell (1982, 1983).

TABLE 5 Comparison of Generalized Models Forecasting Performance

	RMSE	
Commodity	Ordinary	Inverse
Tilapia	0.009	0.018
Milkfish	0.032	0.043
Carp	0.002	0.004
Shrimp	0.059	0.078
Shellfish	0.020	0.029

TABLE 6 Testing for Alternative Generalized Ordinary Model

Model	LR[1]	D.F.[2]	Critical value (5%)
Generalized Ordinary Model			
AIDS	3.4	2	5.99
Rotterdam	24.48	2	5.99
CBS	11.48	2	5.99
NBR	24.42	2	5.99

[1]$-2[\log L(\theta^*) - \log L(\theta)]$.
[2]Degree of freedom.

Their differential AIDS model can be extended to the generalized AIDS (GAIDS) in equation (6). Because the GAIDS model is difficult to use with shorter time series data, a first-order autoregressive distributed lag (ADL) model is usually assumed (p = 1, q = 1). The GAIDS model can then be expressed in an error correction form:

$$\begin{aligned}\Delta(dw_{it}) = {} & e_i' \Delta d\ln Q_t + \Sigma_{j=1}^{5} e_{ij}' \Delta d\ln p_{jt} \\ & - \Sigma_{j=1}^{4} \lambda_{ij} [dw_{jt-1} - \alpha_j - E_j' d\ln Q_{t-1} - \Sigma_{k=1}^{5} E_{jk}' d\ln p_{kt-1}] \\ & + \varepsilon_t \quad i, j = 1, 2, 3, 4, 5 \end{aligned} \tag{6}$$

where e_i' and e_{ij}' are short-run income and price effects, λ_{ij} the adjustment coefficients, E_j' and E_{jk}' long-run income and prices effects, w_{it} budget share of ith aquaculture product in period t, p_{jt} the price of jth aquaculture product in period t, and $d\ln Q = \Sigma_j w_j d\ln q_j$ the Divisia volume index. A diagonal adjustment process is used to avoid having to calculate a large number of parameters with a small sample, that is, λ_{ij} = (if i = j and (ij = (if i(j.

Expression (6) nests other dynamic specifications, including partial adjustment, first-order autoregressive and static model, by imposing some parameter restrictions, allowing us to test the appropriateness of a dynamic specification.

If e′i = E′i and e′ij = E′jk is imposed, the model (6) yields the partial adjustment model:

$$((dwit) = ([(i + E'i\ d\ln Q_t + \Sigma_{j=1}^{5} E_{ij}' d\ln p_{jt} - dw_{it-1}] + \varepsilon_t \tag{7}$$

If $e_i' = E_i'$ and $e_{ij}' = E_{jk}'$ is imposed, the model (6) yields a first-order autoregressive model:

$$\begin{aligned} dw_{it} = {} & \alpha_i \lambda + E_i' d\ln Q_t + \Sigma_{j=1}^{5} E_{ij}' d\ln p_{jt} \\ & + (1 - \lambda)[dw_{it-1} - E_i' d\ln Q_{t-1} - \Sigma_{j=1}^{5} E_{ij}' d\ln p_{jt-1}] + \varepsilon_t \end{aligned} \tag{8}$$

TABLE 7 Testing for Alternative Dynamic Specification

Model	LR[1]	D.F.[2]	Critical value (1%)
GAIDS			
First-order autoregressive	41.24	24	42.97
Partial adjustment	54.96	24	42.97
Static	90.22	28	48.27

[1]–2[log L((*)-log L(()].
[2]Degree of freedom.

Finally, if $\lambda = 1$ is imposed, the model (8) yields a static model:

$$dw_{it} = \alpha_i + E_i' dlnQ_t + \Sigma_{j=1}^{5} E_{ij}' dlnp_{jt} + \varepsilon_t \tag{9}$$

A likelihood ratio test was used to discriminate among the alternative models, including partial adjustment, first-order autoregressive, and static models. Test results show that the first-order autoregressive model was not rejected by the GAIDS model (Table 7), leading us to conclude that consumers do not suddenly adjust the amount they consume in full response to changes in income and prices. For this reason, later in this section we only discuss the results of the first-order autoregressive AIDS model.

ESTIMATION AND RESULTS

The first-order autoregressive AIDS model with homogeneity and symmetry imposed was estimated using Zellner's Seemingly Unrelated Regression (SUR) (Zellner 1962) (SHAZAM version 7.0). The shellfish share equation was dropped due to the problem of singularity in the variance-covariance matrix of the error terms. Estimated parameters can be found in Table 8. Except for milkfish, all expenditure and own price parameters were statistically significant at 5% level. The (parameter, which introduces dynamic aspects into the model, was highly significant, indicating that it might be an important determinant in the demand for aquaculture products. Most of the cross-price parameters were mostly significant. The system R^2 values for the first-order autoregressive AIDS model was 0.9141, indicating that the model performs relatively well in terms of explanatory power.

The uncompensated price and expenditure elasticities calculated at the sample means of aquaculture share are shown Table 9. As expected, all of the own-price elasticities were negative and inelastic except for those calculated for milkfish and shellfish. The demand for milkfish and shellfish was relatively elastic (direct price elasticities of –1.207 and –1.086), while

TABLE 8 The Estimated Parameters of the First-Order Autoregressive AIDS Model with Homogeneity and Symmetry Restrictions Imposed[1]

Estimated parameters	Tilapia	Milkfish	Carp	Shrimp	Shellfish
αI	0.322	–0.039	0.059	0.937	0.279
	(7.084)*	(–0.358)	(7.466)*	(4.820)*	(2.135)*
E'_I	–0.027	0.011	–0.005	–0.091	0.112
	(–5.468)*	(0.796)	(–5.639)*	(–3.851)*	(2.089)*
E'_{i1}	0.035	–0.018	0.000	–0.044	0.026
	(3.217)*	(–2.713)*	(0.150)	(–7.901)*	(2.419)*
E'_{i2}	–0.018	–0.030	–0.001	0.031	0.018
	(–2.713)*	(–1.506)	(–1.080)	(3.146)*	(0.798)
E'_{i3}	0.000	–0.001	0.006	–0.008	0.003
	(0.150)	(–1.080)	(4.824)*	(–6.439)*	(1.533)
E'_{i4}	–0.044	0.031	–0.008	0.074	–0.054
	(–7.901)*	(3.146)*	(–6.439)*	(4.138)*	(–2.574)*
E'_{i5}	0.026	0.019	0.003	–0.054	0.006
	(2.419)*	(0.798)*	(1.533)	(–2.574)*	(2.685)*
λ	0.754	0.754	0.754	0.754	0.754
	(7.504)*	(7.504)*	(7.504)*	(7.504)*	(7.504)*

[1]t-ratios are in parentheses.
*Statistically different from zero at $\alpha = 0.05$ level.

tilapia, carp, and shrimp were relatively inelastic (−0.635, −0.652, and –0.759). The own-price elasticities of milkfish and shellfish were more than 1, which indicates that milkfish and shellfish can be promoted by reducing their prices. We also found the expenditure elasticities of milkfish and shellfish to be more than one, indicating they ranked most responsive to aquaculture product expenditures. Consumer preferences for milkfish and shellfish changed. The uncompensated cross-price elasticities were generally small, implying that aquaculture demands are weak gross substitutes (or complements).

TABLE 9 Expenditure and Uncompensated Price Elasticities at Mean Values[1]

	Tilapia	Milkfish	Carp	Shrimp	Shellfish
Expenditure elasticities (η_i)	0.746*	1.068	0.727*	0.816*	1.488*
Uncompensated price elasticities (e_{ij})					
Tilapia	–0.635*	–0.127*	0.043	–0.069*	0.062*
Milkfish	–0.137*	–1.207	–0.036	0.091*	0.004*
Carps/Carp	0.007	–0.010	–0.652*	–0.013*	0.004
Shrimp	–0.292*	0.171*	–0.315*	–0.759*	–0.477*
Shellfish	0.311*	0.105	0.232	–0.067*	–1.086*

[1]The expenditure elasticity and uncompensated price elasticity are obtained from the formulae: $\eta_i = (E'_i/w_i) + 1$ and $e_{ij} = (E'_{ij}/w_i) - E'_i(w_j/w_i)$.
*Statistically different from zero at $\alpha = 0.05$ level.

CONCLUSIONS

This study uses modified non-nested testing techniques (Davidson & Mackinnon 1983) and forecasting performance to determine which generalized model could best estimate demand for Taiwanese aquaculture products. Although our approach is not new, our study represents the first time it has been used to analyze the demand for aquaculture products in Taiwan. The generalized ordinary demand model using RMSE measures was able to better forecast performance than the generalized inverse demand model.

In this study, special attention has been paid to the presence of inertia and the persistence of habits of consumer behavior. Because the autoregressive specification fit the data better in this study, we can assume that there is a certain amount of inertia in the demand for aquaculture products in Taiwan, meaning that a change in demand would not be instantaneous but delayed when made in response to changes in prices and expenditures.

The model we finally used to estimate demand showed that, as expenditure increases, people tend to buy more milkfish and shellfish and buy less of the other aquaculture products, particularly carp and tilapia. Moreover, the own-price elasticities of milkfish and other shellfish were found to be greater, suggesting that consumption of these two products is more responsive to own-price changes than the other aquaculture products. Therefore, retail price could be used more effectively to promote milkfish and shellfish than the other products.

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